

## PART II: RECOVERY

### RECOVERY OBJECTIVE

The objective of this recovery plan is to assure the long-term viability of the Hine's emerald dragonfly by arresting or reversing its decline and addressing threats to its survival. When this objective is achieved, the Hine's emerald dragonfly may be removed from the Federal list of *Endangered and Threatened Wildlife and Plants* (50 CFR 17.11 and 17.12).

The recovery criteria are based on the available information for the Hine's emerald dragonfly and related odonate species and on basic principles of conservation biology. As additional information on the life history, ecology, population dynamics, and current status of this species becomes available, it may be necessary to revise these criteria.

Figure 5 illustrates the location of the recovery units.

### CRITERIA FOR RECLASSIFICATION TO THREATENED

The Hine's emerald dragonfly will be considered for reclassification from endangered to threatened status when all of the following criteria are achieved:

**1. Each of the two Recovery Units contains a minimum of two populations, each composed of at least three subpopulations. Each subpopulation contains a minimum of 500 sexually mature adults for 10 consecutive years.**

The number 500 is intended to represent the annual effective population size (the number of adult dragonflies that emerge over the flight season and mature to be capable of reproducing) of the population or subpopulation, rather than the number of adult dragonflies present at any one moment. Census techniques used to determine whether the population size criterion has been met may only be able to provide an estimate of relative population sizes. Relative population size estimates will be affected by several factors regarding Hine's emerald dragonfly population dynamics that are still unknown, including sex ratios, differential survival of males and females post-emergence, and survival probabilities in transitions from one life stage to the next (*e.g.*, late instar larvae to teneral, teneral to reproductive adults). It is understood that resources for monitoring populations are limited, that some sites may be too fragile to support annual monitoring, and that research to improve population size estimates is a priority.

**2. Within each subpopulation, there are at least two breeding habitat areas, each fed by separate seeps and/or springs.**

Because a breeding area within a single drainage system would be vulnerable to loss from events such as contamination and hydrological changes, it is important to have another site with potential breeding habitat available that may not be affected by the same event or events. A back-up breeding habitat area would reduce the risk of losing an entire subpopulation, such as might occur if all the larvae were concentrated in one breeding area during a drought.

**3. For each population, the habitat supporting at least two subpopulations should be legally or formally protected and managed for Hine's emerald dragonfly, using long-term protection mechanisms such as watershed protection, deed restrictions, land acquisition, or nature preserve dedication. In addition, mechanisms protecting the up gradient groundwatershed should also be in place.**

**4. A monitoring plan must be established for each population within 5 years to estimate population size on an annual basis for the purpose of determining whether recovery criteria have been achieved.**

## **CRITERIA FOR DELISTING**

The Hine's emerald dragonfly will be considered for delisting when all of the following criteria are achieved:

**1. Each of the two Recovery Units contains a minimum of three populations composed of at least three subpopulations. Each subpopulation contains a minimum of 500 reproductive adults for 10 consecutive years.**

**2. Within each subpopulation, there are at least two breeding habitat areas, each fed by separate seeps and/or springs.**

**3. For each population, the habitat supporting at least three subpopulations should be legally or formally protected and managed for Hine's emerald dragonfly, using long-term protection mechanisms such as watershed protection, deed restrictions, land acquisition, or nature preserve dedication. In addition, mechanisms protecting the up gradient groundwatershed will also be in place within 5 years.**

## **STEPDOWN RECOVERY OUTLINE**

1. PROTECT AND MANAGE EXTANT POPULATIONS
  - 1.1 Protect extant populations
    - 1.1.1 Review Federal, state, and private activities
    - 1.1.2 Develop recovery implementation strategies to promote recovery
    - 1.1.3 Determine watershed ownership
    - 1.1.4 Long-term watershed habitat protection
      - 1.1.4.1 Land protection
      - 1.1.4.2 Groundwater protection
  - 1.2 Monitor extant populations
    - 1.2.1 Annual monitoring
      - 1.2.1.1 Presence/absence surveys
      - 1.2.1.2 Census surveys
    - 1.2.2 Annual intensive monitoring
      - 1.2.2.1 Intensive larval monitoring
      - 1.2.2.2 Intensive adult monitoring
  - 1.3 Manage habitat
    - 1.3.1 Illinois
      - 1.3.1.1 Black Partridge Forest Preserve
      - 1.3.1.2 Keepataw Forest Preserve
      - 1.3.1.3 Lockport Prairie Nature Preserve
      - 1.3.1.4 Long Run Seep Nature Preserve
      - 1.3.1.5 McMahon Woods
      - 1.3.1.6 Middle Parcel
      - 1.3.1.7 River South Parcel
      - 1.3.1.8 Romeoville Prairie Nature Preserve
      - 1.3.1.9 Waterfall Glen Forest Preserve
    - 1.3.2 Wisconsin
      - 1.3.2.1 The Ridges Sanctuary
      - 1.3.2.2 Mink River
      - 1.3.2.3 Mud Lake “North”
      - 1.3.2.4 Mud Lake “South”
      - 1.3.2.5 Arbter Lake, North Bay, and Three Springs Creek
      - 1.3.2.6 Piel Creek
      - 1.3.2.7 Cedarburg Bog
    - 1.3.3 Michigan
      - 1.3.3.1 Acklund Road, Brevort Lake Road, Horseshoe Bay, I-75 East, I-75 West, Martineau Creek SW, and Summerby Swamp
      - 1.3.3.2 Snake Island Fens
      - 1.3.3.3 Loop 2 Fen
      - 1.3.3.4 Misery Bay
    - 1.3.4 Missouri
      - 1.3.4.1 Grasshopper Hollow

- 1.3.5 New sites as they are verified
    - 1.3.5.1 Additional Sites
- 2. CONDUCT STUDIES
  - 2.1 Population ecology
    - 2.1.1 Larval ecology
    - 2.1.2 Adult ecology
    - 2.1.3 Model population dynamics
  - 2.2 Monitoring synthesis
    - 2.2.1 Correlate larval and adult population sizes
    - 2.2.2 Analyze techniques for estimating population size
  - 2.3 Hydrologic studies
    - 2.3.1 Illinois
      - 2.3.1.1 Lockport Prairie Nature Preserve, Romeoville Prairie Nature Preserve, Middle Parcel, River South Parcel, and Keepataw Forest Preserve
      - 2.3.1.2 Waterfall Glen Forest Preserve
      - 2.3.1.3 Black Partridge Forest Preserve and McMahon Woods
      - 2.3.1.4 Long Run Seep Nature Preserve
    - 2.3.2 Wisconsin
      - 2.3.2.1 The Ridges Sanctuary and Mud Lake “North”
      - 2.3.2.2 Mud Lake “South”
      - 2.3.2.3 Arbter Lake
      - 2.3.2.4 North Bay
      - 2.3.2.5 Three Springs Creek
    - 2.3.3 Michigan
    - 2.3.4 Missouri
    - 2.3.5 New sites as they are verified
  - 2.4 Genetics
  - 2.5 Habitat management studies
    - 2.5.1 Evaluate responses to habitat management practices
  - 2.6 Roadkill studies to include strategies for minimizing roadkills
  - 2.7 Water quality monitoring
  - 2.8 Effects of environmental contaminants
    - 2.8.1 Contaminants
    - 2.8.2 Mosquito abatement programs
- 3. CONDUCT SEARCHES FOR ADDITIONAL POPULATIONS
  - 3.1 Search for larval habitat within existing sites
  - 3.2 Search for additional populations in Michigan
  - 3.3 Search for populations in Alabama
  - 3.4 Search for additional populations in Missouri
  - 3.5 Search for additional populations in Wisconsin
  - 3.6 Search for populations in Ohio

- 3.7 Search for populations in Indiana
- 3.8 Search for populations in New York
- 3.9 Search for populations in Maine
- 3.10 Search for populations in Arkansas, Iowa, Illinois, Kentucky, Minnesota, Tennessee, West Virginia, and Canada
- 3.11 Assess potential for Hine's emerald dragonfly in other states
- 4. REINTRODUCTION, INTRODUCTION, AND AUGMENTATION PROGRAM
  - 4.1 Develop captive rearing protocols
  - 4.2 Implement captive rearing program
  - 4.3 Assess sites for reintroduction, introduction, or augmentation
    - 4.3.1 Illinois
    - 4.3.2 Wisconsin
    - 4.3.3 Michigan
    - 4.3.4 Ohio and Indiana
  - 4.4 Implement reintroduction, introduction, or augmentation
  - 4.5 Monitor reintroduced, introduced and/or augmented populations annually
- 5. CONDUCT AN INFORMATION AND EDUCATION PROGRAM
  - 5.1 Encourage private landowners to conserve the Hine's emerald dragonfly
  - 5.2 Inform local and county governments of recovery goals
  - 5.3 Develop outreach material on life history and conservation
- 6. REVIEW AND TRACK RECOVERY PROGRESS
  - 6.1 Maintain a clearinghouse for Hine's emerald dragonfly information
  - 6.2 Conduct Recovery Team meeting(s) at least biannually to evaluate progress
  - 6.3 Revise plan as appropriate at 5 year intervals

## STEPDOWN NARRATIVE OUTLINE

### 1 PROTECT AND MANAGE EXTANT POPULATIONS

**1.1 Protect extant populations.** Protection should be executed to the highest degree necessary at the Federal, state, and local levels. The private sector should be encouraged to participate in the protection of this species and its habitat. It is unknown what relative importance each subpopulation may have to the sustainability of the entire population. Recent research indicates that sink populations may play an important role in recolonizing source habitat after a sudden extirpation of a source population due to a chance event (Thomas *et al.* 1996). Because small populations can serve as sources for colonists, even small populations are valuable and should be protected. For example, some of the moderate-sized populations in Illinois are known to contain unique haplotypes based upon mitochondrial DNA analysis (Purdue *et al.* 1996). Protection efforts should target populations with genetically unique stocks.

**1.1.1 Review Federal, state, and private activities.** The extant populations occupy both public and private land. The public sites include Federal, state, and county government land holdings that have varying degrees of legal protection. Many of the identified threats to this species are from off-site activities, such as the alteration of water quality and quantity, and road maintenance and construction. All Federal, state, and private activities and permits should be carefully reviewed for direct and indirect impacts. ESA section 7 consultations should be used whenever appropriate, such as in conjunction with section 404 Clean Water Act permits administered by the United States Army Corps of Engineers, and roadway projects funded by the Federal Highway Administration.

For roadways of concern, the USFWS and state agencies should review road construction and maintenance plans including salt application, culvert maintenance or replacement, regrading, regravelling or resurfacing of the road, or other changes to the roads that could impact the habitat. Potential impacts from roadway activities include a decrease in water quality due to salt input, contaminated surface runoff, alteration of hydrology, siltation, and loss of breeding habitat due to filling. The impounding effects of the road may also decrease larval habitat. Possible ways to enhance larval habitat by altering roadway and/or culvert placement should be assessed. Existing highways of concern include Highway 53 and Route 7 in Illinois, Highway 57 and County Q in Wisconsin, and Interstate 75 and Mackinac Trail in Michigan.

**1.1.2 Develop recovery implementation strategies to promote recovery.** It is important to encourage public participation in implementation of recovery actions. Participation strategies/plans should be developed as appropriate that facilitate implementation of this plan. These efforts may focus on one aspect of recovery, such as a single population or a single task. Representatives of all interested parties that could be affected by implementation of the recovery actions and/or could assist with recovery implementation (include Federal and State

agencies, and members of the public including private landowners, companies, private citizens, and conservation groups) should be encouraged to participate. Education and outreach activities may provide a vital link for involving stakeholders in development of recovery strategies, especially in recovery areas that include or may affect private lands.

**1.1.3 Determine watershed ownership.** The ownership of all sites in Illinois is known and referenced in this Plan. The ownership of some Wisconsin sites needs to be determined to facilitate protection and management. Most of the Michigan sites are managed by the United States Forest Service's Hiawatha National Forest. Ownership of any new sites should be determined as soon as possible after the discovery to enable protection and management as appropriate. Ownership of important areas within watersheds supporting Hine's emerald dragonfly should also be determined to facilitate protection.

**1.1.4 Long-term watershed habitat protection.** It will be necessary to implement strategies to guarantee long-term habitat protection of the geographic land base (including recharge areas) necessary to support viable populations. This might be accomplished by land acquisition, conservation easements, management agreements, habitat conservation plans, or other means. Working cooperatively with landowners, other agencies (e.g., Natural Resources Conservation Service), and/or organizations may also facilitate habitat protection.

**1.1.4.1 Land protection.** All available measures should be explored to provide long-term protection and management of the private and public sites inhabited by Hine's emerald dragonfly and the important habitat within the watersheds that support these sites. Priority areas include non-protected existing breeding habitat and their associated groundwatershed. Measures to protect privately-owned habitat may include voluntary registries, management agreements, acquisition of development rights, easements, or purchase on a willing seller basis. Private non-profit organizations may also assist public agencies in protection and management efforts. For those public sites not currently protected under the highest level allowable in each state, higher levels of protection should be pursued.

**1.1.4.2 Groundwater protection.** Maintaining an appropriate amount of groundwater flow, as rivulets or as sheet flow, appears to be essential to the larval habitat. Since the larvae are believed to spend 2 to 4 years in aquatic systems supported by groundwater, the groundwater quantity and quality become important elements of the habitat. To protect this species, protection of groundwater quality and quantity is needed. Groundwatershed planning and protection is also needed so that groundwater discharge at breeding sites is not impacted. Baseline data gathered from conducting hydrologic studies would be valuable information in protecting the groundwater.

**1.2 Monitor extant populations.** Extant populations of Hine’s emerald dragonfly should be monitored to estimate population size and track population stability and trends over time. It is recognized that not all sites may be intensively monitored to estimate population numbers on an annual basis due to resource constraints and fragility of habitat. Currently, Lockport Prairie Nature Preserve in Illinois and Mud Lake “North” in Wisconsin are proposed for intensive annual census surveys. A more general monitoring plan is recommended for land managers able to devote resources to tracking the population trends at their sites. Where no other monitoring is possible at a site, observations of the presence of Hine’s emerald dragonflies at a site should be noted annually. Research to improve population census methods using both adults and larvae is a priority for this species; therefore, land managers and researchers intending to begin monitoring efforts on potential habitat should contact the USFWS, Chicago Illinois Field Office, 1250 South Grove, Barrington, Illinois 60010, for updated information on monitoring techniques and permit requirements.

**1.2.1 Annual monitoring.**

**1.2.1.1 Presence/absence surveys.** Presence/absence surveys should be conducted at all sites that are not otherwise being monitored.

**1.2.1.2 Census surveys.** Census surveys provide estimates of relative abundance. This survey is recommended when funding and effort are available.

**1.2.2 Annual intensive monitoring.** Annual intensive monitoring that provides more information on population health and population trends will be used to research monitoring methods and link larval and adult population estimates. One subpopulation within each of the populations in Illinois and Wisconsin should be monitored intensively each year. An appropriate area in Michigan for annual intensive monitoring has not been identified.

**1.2.2.1 Intensive larval monitoring.** Annual intensive larval monitoring is recommended at one of the subpopulations in each of the populations. Currently, the Illinois and Wisconsin populations are the only populations with known population sizes large enough to survey for larvae. Information from intensive larval monitoring will be used to correlate larval and adult population sizes in task 2.2.1 and will aid in tracking the population status and population trends.

**1.2.2.2 Intensive adult monitoring.** Annual intensive adult monitoring is recommended at one of the subpopulations in each of the populations. Currently, the Illinois and Wisconsin populations are the only populations with known population sizes large enough to survey for Hine’s adults. Information from intensive adult monitoring will be used to correlate larval and adult population sizes in task 2.2.1 and will aid in tracking the population status and population trends.



- 1.3 Manage habitat.** Caution should be taken when management techniques are executed within Hine's emerald dragonfly habitat due to the lack of information on the effects of management practices on this species. The effects on the dragonfly from habitat-altering management techniques should be monitored closely. Management actions should be reviewed by the USFWS and the state's Department of Natural Resources and appropriate Recovery Team experts. Section 10 permits will be required if management actions will result in harm to the dragonfly.

Habitat management plans should be developed to incorporate adaptive management techniques as habitat requirements for the Hine's emerald dragonfly become more clear and its responses to management techniques more evident. These plans should address promoting habitat diversity and reducing threats to this species.

A team of local site managers should work together to develop management plans and guidelines for each population on a landscape level to promote population recovery and health. For example, a team of local site managers could review options to increase connectivity between the Hine's emerald dragonfly sites in areas that are outside of their particular sites. An exchange of information between land managers and research scientists should be facilitated to promote the best use of management techniques and to potentially improve research application and design. The USFWS, Chicago Field Office, is currently a clearinghouse of information for the Hine's emerald dragonfly (task 6.1), which will increase the accessibility of updated information to both researchers and land managers.

Habitat management concerns differ between sites as well as the techniques used to remedy them. These concerns include brush encroachment, invasion of non-native species, hydrology alteration, siltation, and groundwater and surface water quality and quantity. Management techniques that might be implemented at some locations are prescribed burns, non-native plant control, and hydrologic controls. Managers using prescribed burns should consider the frequency and timing of burning so that it reduces potential adverse impact to dragonflies survival by removal of essential cover. Brush cutting should occur when the ground is frozen to reduce impacts to the substrate. Forest edges should be a component of the habitat as these areas provide perching, resting, and foraging habitat as well as cover and mating sites for the dragonfly. Management activities should be varied across each site and season, consistent with invertebrate conservation and ecosystem management theory, so that insect populations are not uniformly affected by the management activities. (Schlict and Orwig 1992, USFWS 1993b, Panzer *et al.* 1995, Swengel 1996, Packard and Mutel 1997, Schultz and Crone 1998).

- 1.3.1 Illinois.** Management of the Hine's emerald dragonfly habitat is necessary to maintain proper conditions for successful breeding and foraging. A burn rotation may be beneficial to the dragonfly. However, further data is needed to determine the burn frequency, since too much thatch reduction may reduce habitat suitability and increase the potential for drought and dessication. Other threats such as hydrology alteration, siltation, and encroaching non-native species can also be

addressed to a limited degree through site management. The entity responsible for the management at each site is identified below within the parentheses in tasks 1.3.1.1 to 1.3.1.9.

**1.3.1.1 Black Partridge Forest Preserve, Cook County** (Cook County Forest Preserve District). Black Partridge Forest Preserve hosts a low density of Hine's emerald dragonflies. The dragonflies are not seen in some years. Management should focus on improving breeding habitat with the goal of increasing the population size at this site. Brush encroachment should be considered as a possible factor reducing habitat suitability. Threats that should also be considered include water quality degradation from a proposed multi-lane highway adjacent to the preserve and existing roadways.

**1.3.1.2 Keepataw Forest Preserve, Will County** (Will County Forest Preserve District). This site has a small confirmed breeding population. Brush cutting has already taken place outside a 25 foot buffer zone around several seeps emanating from the bluff as part of the mitigation for a local quarry expansion. Opening of the seep areas may benefit the dragonfly. Breeding was observed after brush cutting had occurred. Additional brush reduction should be considered. Erosion on the bluff face into seep areas is a threat in some areas. The bluff face is artificially steep from historic mining and some effort may be needed to keep hikers and others from exacerbating this erosion into the seeps.

**1.3.1.3 Lockport Prairie Nature Preserve, Will County** (Will County Forest Preserve District). This site has one of the largest confirmed breeding portions of the Illinois population. This Nature Preserve is managed by the Forest Preserve District under a long-term lease agreement with the Metropolitan Water Reclamation District of Greater Chicago. The primary management goal of the preserve incorporates an ecosystem based approach and involves the maintenance of all the state and federally listed threatened and endangered species populations that occur within the site, as well as the integrity of the natural plant communities.

The current rotational prescribed burn schedule should be coordinated with any further research on the effects of prescribed burn frequency upon the dragonfly's breeding habitat. Beaver management may also be needed to sustain appropriate hydrology. One beaver tube, a management device that allows water to flow through a beaver dam, has already been installed at this preserve. Ongoing monitoring of several structures installed to carry groundwater beneath the railroad to the breeding habitat will be needed. The purpose of these structures is to restore historic hydrology. Expected benefits from the water control structures include the enhancement of high quality wetland, reduction of non-native species encroachment, and enhancement of breeding and foraging habitat for

several endangered and threatened species, including the Hine's emerald dragonfly. The control of reed canary grass is a management need. The operational management of the railroad through this Nature Preserve is reviewed by a Right-of-Way Management Team that includes the USFWS (described below for the River South Parcel, Will County).

- 1.3.1.4 Long Run Seep Nature Preserve, Will County** (Illinois Department of Natural Resources). Long Run Seep is a state-owned and managed nature preserve. This site has the third largest portion of the Illinois population. Similar to the other sites, ongoing management includes prescribed burns on a rotational schedule. Non-native species control for species such as purple loosestrife is ongoing and will continue to be needed. Woody non-native species such as buckthorn are starting to become a problem at this preserve and will need to be addressed in the future. The watershed to this preserve is undergoing rapid development and water quality and quantity should be monitored and managed.
- 1.3.1.5 McMahon Woods, Cook County** (Cook County Forest Preserve District). No dragonflies have been reported at this site since 1993. McMahon Woods has potential Hine's emerald dragonfly breeding habitat. Male Hine's emerald dragonflies exhibiting territorial behavior and teneral adults have been observed at this site. This site may not produce Hine's emerald dragonfly adults every year because the water levels at this site fluctuate drastically from year to year. Management concerns that should be evaluated at this site include increasing cattail density around potential breeding habitat, controlling buckthorn encroachment, and addressing the degradation of water quality due to bluff erosion. A potential problem at McMahon Woods is the apparent lowering of the water table; therefore, the hydrology at this site should be examined and monitored closely.
- 1.3.1.6 Middle Parcel, Will County** (Material Service Corporation). The Middle Parcel contains a relatively small breeding population and is near the River South Parcel, which contains one of the largest Illinois populations. Material Service Corporation, a mining company, operates an adjacent limestone quarry. The site is not actively managed and has been proposed for mining. Site management could include rotational prescribed burning, brush cutting at the base of the bluff/berm at the western edge, and water quality and quantity monitoring.
- 1.3.1.7 River South Parcel, Will County** (Material Service Corporation). This site contains one of Illinois' largest breeding populations. The habitat and dragonflies at this site have been intensively studied and monitored. Two prescribed burns have been conducted over portions of the site, although no further management is planned by the landowner. A Commonwealth Edison (ComEd) utility corridor and railroad pass

through this site, between the bluff seeps and the wetland used by the dragonfly. As a result of a Clean Water Act permit, ComEd is conducting several studies assessing potential impacts from the railroad rehabilitation and operation. In addition, the USFWS coordinates a Right-of-Way Management Team, made up of railroad personnel, adjacent landowners, and resource agencies. The Management Team reviews and addresses all issues and concerns regarding the operational maintenance of the railroad and the management of the site, relative to potential benefits or impacts to the dragonfly. The ComEd studies, the Management Team, and any additional studies should guide management at this privately-owned site.

**1.3.1.8 Romeoville Prairie Nature Preserve, Will County** (Will County Forest Preserve District). A limited number of dragonfly observations have been reported from this site. The site is currently managed as a natural area with prescribed burns. The control of reed canary grass is a management need. As additional information on breeding habitat requirements becomes available, management should focus on increasing breeding habitat.

**1.3.1.9 Waterfall Glen Forest Preserve, Du Page County** (Du Page County Forest Preserve District). One small seep area within this preserve supports a small breeding population. This large preserve surrounds Argonne National Laboratory and is managed as a natural area. Management of the seep area and adjacent marsh with prescribed burning and brush cutting should be continued to maintain open habitat for breeding.

**1.3.2 Wisconsin.** The recommended management actions for each site are discussed below. General guidelines for new sites include continuing existing management techniques until further information about site enhancement is determined. Management plans should be adapted to identify and implement management actions that enhance the survival of the Hine's emerald dragonfly. If nearby areas have been quarried, measures should be taken to revegetate the quarry to enhance foraging habitat. The entity responsible for the management at each site is identified below within the parentheses in tasks 1.3.2.1 to 1.3.2.7.

**1.3.2.1 The Ridges Sanctuary, Door County** (The Ridges Sanctuary, Inc.). The Ridges is believed to support the largest Hine's emerald dragonfly population in Wisconsin. Larvae occur at this site. It is recommended that The Ridges continue to be managed as a natural area, maintaining breeding and adult foraging habitats. Management efforts should include the control of non-native species such as reed canary grass and purple loosestrife in the watershed. The presence of dense stands of purple loosestrife and/or reed canary grass may impair the ability of the

dragonfly to reach seeps or streams for egg laying (P. Regnier, The Ridges Sanctuary, pers. comm. 1999). Management should also focus on maintaining the hydrology of the site by supporting hydrologic research and working with the Town of Baileys Harbor in watershed protection efforts.

- 1.3.2.2 Mink River, Door County** (The Nature Conservancy). The Nature Conservancy (TNC) owns this site, and it is recommended that TNC continue to manage the Mink River as a natural area. One Hine's emerald dragonfly adult was collected from Mink River in 1987.
- 1.3.2.3 Mud Lake "North", Door County** (Wisconsin Department of Natural Resources). This site is part of the Mud Lake Wildlife Area (Mud Lake), owned and managed by the Wisconsin Department of Natural Resources (Wisconsin DNR). This site supports the largest known larval population in Wisconsin. It is recommended that the Wisconsin DNR continue to manage this area as a natural area, maintaining breeding areas and adult foraging habitat. Any management plans that may alter the hydrology of this site, or degrade breeding or adult foraging habitat (e.g. logging), should be coordinated with the USFWS, the Wisconsin DNR's Bureau of Endangered Species, and appropriate members of the recovery team. This includes removal of beaver impoundments or the adjustments of beaver control structures. Beaver impoundments may have created an open meadow at this site, which is considered desirable adult Hine's emerald dragonfly habitat. Wisconsin DNR should consider applying appropriate management techniques (e.g., allowing occasional beaver impoundments to exist) to keep trees from invading the meadow.
- 1.3.2.4 Mud Lake "South", Door County** (Wisconsin DNR). This site is also part of the Mud Lake Wildlife Area, owned and managed by the Wisconsin DNR. The dragonfly breeds at this site. It is recommended that Wisconsin DNR continue to manage this site as a natural area. Any management plans that may alter the hydrology of the site or degrade breeding or foraging habitat should be coordinated with the USFWS, the Wisconsin DNR's Bureau of Endangered Species, and appropriate members of the recovery team.
- 1.3.2.5 Arbter Lake, North Bay, and Three Springs Creek, Door County** (Private ownership). Arbter Lake, North Bay, and Three Springs Creek sites are privately-owned. Breeding has been confirmed at all three sites. North Bay and Three Springs Creek sites occur within a TNC project area. Landowners should be contacted to discuss opportunities for management to maintain dragonfly habitat.
- 1.3.2.6 Piel Creek, Door County** (Private ownership; TNC project area). Piel Creek and adjacent wetlands are primarily in private ownership.

Landowners should be contacted to discuss opportunities for management to maintain dragonfly habitat. The north end of Kangaroo Lake and much of Piel Creek are within a TNC project area. Wetlands associated with the north end of Kangaroo Lake and the mouth of Piel Creek are contained within the Kangaroo Lake Land Trust. If it is determined that Hine's emerald dragonflies breed at this site, the creek should be checked yearly for beaver impoundments. Culvert replacement or construction projects that could affect the hydrology of the area (e.g., along Kuchar's old farm road) should be reviewed to ensure they do not negatively affect breeding habitat.

**1.3.2.7 Cedarburg Bog, Ozaukee County** (University of Wisconsin and Wisconsin DNR). Cedarburg Bog is jointly-owned and managed by the Wisconsin DNR and the University of Wisconsin-Milwaukee. The DNR land is designated a State Scientific Area and the university portion of the site is managed as a biological field station.

**1.3.3 Michigan.** The recommended management actions for each site are discussed below. General guidelines for new sites include existing management techniques until further documentation on larval habitats can be determined. Management plans should be adapted to identify and implement management actions that enhance the survival of the Hine's emerald dragonfly. The entity responsible for the management at each site is identified below within parentheses in tasks 1.3.3.1 to 1.3.3.4.

**1.3.3.1 Acklund Road, Brevort Lake Road, Horseshoe Bay, I-75 East, I-75 West, Martineau Creek SW, and Summerby Swamp, Mackinac County** (Hiawatha National Forest). All of the currently known sites in the Upper Peninsula are located on Hiawatha National Forest lands in Mackinac County and are managed by the U.S. Forest Service. These sites are fairly pristine and currently face fewer threats than the sites in other states. Management for invasion of non-native plant species, destruction of habitat by off-road vehicles, road and utility right-of-way maintenance, and logging can be addressed through site management plans and Michigan DNR environmental review process.

**1.3.3.2 Snake Island Fens, Mackinac County** (Michigan DNR-dedicated Natural Area; Private ownership). The potential breeding habitat at the Snake Island Fens site is split between land owned by the state of Michigan (Snake Island-Mud Lake Natural Area) and private lots (Steffens 1999). If it is determined that Hine's emerald dragonflies breed at this site, the creek should be checked yearly for beaver impoundments. Culvert replacement or road construction projects that could affect the hydrology of the area should be reviewed to ensure they do not negatively affect breeding habitat. Landowners should be contacted to discuss opportunities for management to maintain dragonfly habitat.

#### **1.3.3.3 Loop 2 Fen, Presque Isle County** (Michigan DNR Parks Division).

This site is currently an undeveloped state park with a few hiking trails, parking areas, and a gravel road that transects the park. It is recommended that the Michigan DNR continue to manage this site as a natural area. Any management plans that may alter the hydrology of the site or degrade breeding or foraging habitat should be coordinated with the USFWS, Michigan DNR Endangered Species Coordinator, and appropriate members of the recovery team. Management to prevent destruction of habitat by off-road vehicles and road and utility right-of-way maintenance can be addressed through site management plans and Michigan DNR environmental review process.

**1.3.3.4 Misery Bay, Alpena County** (Private ownership). This wetland is owned by a group of individuals from Detroit known as the Beaumont Corp. The owners use the area for hunting and other outdoor recreational activities. There are no developments currently on the property other than narrow gravel roads and hunting camps (Steffens 1999). Landowner contact should be continued to discuss opportunities to maintain dragonfly habitat.

### **1.3.4 Missouri.**

#### **1.3.4.1 Grasshopper Hollow, Reynolds County** (Doe Run Mining Company).

The area where the Hine's emerald dragonflies were observed is owned by the Doe Run Mining Company and leased to The Nature Conservancy. At 10 acres, this is the largest prairie fen known in unglaciated North America. Historically the area was grazed and probably cut for hay. The surrounding forested areas have been logged. Deep hard rock mining for lead and other metals has been active for about 25 years in this area of the State. Beavers have impounded portions of the fens and deep muck fens adjacent to the prairie fen. Their impoundments change the water depth, flow, and vegetation. Occasional removal of beavers has helped reduce their activities. The Nature Conservancy plans to limit the beaver numbers. Alder and hazel growth has increased remarkably in recent years. Grazing, mowing, and fire probably kept these in check in the past. Control measures, particularly prescribed burns, are planned to help reduce the woody plants and open areas for other vegetation.

### **1.3.5 New sites as they are verified.**

**1.3.5.1 Additional Sites.** Additional sites that should be assessed to determine habitat management needs are the Kellner Fen, Ephraim Swamp, and Big Marsh (Washington Island) in Door County, Cedarburg Bog in Ozaukee County, the Black Ash Swamp in Kewaunee County, and any new sites identified in the future. Landowners should be

contacted, as appropriate, to discuss opportunities for management to maintain breeding and adult Hine's emerald dragonfly habitats.

## 2 CONDUCT STUDIES

**2.1 Population ecology.** Where possible, unlisted species closely related to the Hine's emerald dragonfly should be used as surrogates in research projects. In addition, data from comparative studies with closely related species should be consulted.

**2.1.1 Larval ecology.** Conduct studies to determine larval ecology and abundance, larval life history, phenology, and interspecific interactions.

Larval ecology and abundance: Larval studies should continue to determine 1) which sites support reproducing populations, 2) which particular habitats within sites support larvae, 3) abundance of larvae within the particular habitats, 4) the diet of the larvae in comparison to prey abundance in the larval habitat, and 5) interspecific interactions. This information should provide insight on the habitat requirements of Hine's emerald dragonfly larvae. Studying the differences between habitat known to support Hine's emerald dragonfly larvae and similar habitat within sites known to be inhabited by adults also could provide information on larval habitat requirements. In addition to these studies, seasonal sampling should be conducted to examine changes in size distribution patterns, which will aid in determining growth rates and phenology. Information on larval ecology is essential for developing a more complete understanding of life history and ecological requirements, and also provides valuable information on population structure. If reintroduction or augmentation is needed for this species, information on larval ecology would be essential.

Larval life history: Research should be conducted to determine 1) period of egg development, 2) the proportion of eggs that survive to larval stage, 3) larval survivorship to adult stage, 4) the length of larval development. This information is important in determining this species' reproductive potential and constructing the life table in task 2.1.3.

Phenology: Studies to understand the role of drought tolerance in the population biology should continue. Hine's emerald dragonfly larvae have been observed to tolerate a certain amount of habitat drying, and it appears that most known sites are subject to periods of drought during the summer. Extension of ongoing studies, evaluating this species' behavioral and morphological adaptations to drought conditions is especially important. Additional studies to complement ongoing work that examines how potential competitors and predators are affected by drought are also important. Tracking drought frequency of known larval habitat is central to any ongoing research on Hine's emerald dragonfly populations. This information would also aid in understanding the hydrology of the wetland ecosystems inhabited by Hine's emerald dragonfly. Drought tolerance studies along with a long-term study that correlates drought periodicity



and larval densities may be used to determine when larval habitat becomes too dry for larval survival. This information is essential for assessing the risk to Hine's emerald dragonfly populations from any hydrological alteration of their habitat (groundwater pumping, diversion, draining, etc.), and is required before any management techniques that artificially manipulate wetland hydrology are implemented or developed.

Interspecific interactions: Little is known about the interactions between the Hine's emerald dragonfly larvae and their predators. Understanding how predators influence survival, growth rate, and/or reproduction is essential for understanding the population dynamics of this species (Wissinger 1992). Studies should be conducted to determine which predators may kill significant numbers of Hine's emerald dragonflies. A logical first step would be to conduct diet analysis of potential predators in the same habitat to determine which consume the dragonfly. Studies should also be conducted to determine if the presence of predators change the diet, food availability, and growth rate of the larvae. Enclosure experiments using species closely related to the Hine's emerald dragonfly may provide insight on its responses to predators.

The abundance and diversity of potential predators should be evaluated in larval habitat to determine if changes in the species composition and density of predators affect Hine's emerald dragonfly larval densities. If a substantial decline in larval densities occurs, the species composition should be assessed to determine if there have been changes in predator abundance or diversity. Management actions may result in shifts in species composition within larval habitat. This information could be useful in evaluating management techniques.

Little is known about how competitors affect Hine's emerald dragonfly larval development and survival. This information is useful when assessing population dynamics (Wissinger 1992). The abundance of competitors in a streamlet may influence the abundance of Hine's emerald dragonflies. Alterations of the hydrology or habitat may influence the type and/or abundance of competitors that may affect Hine's emerald dragonfly larval densities.

Diet analysis of potential competitors along with prey abundance is useful when determining which species are likely to be competitors and the level of impact a particular competitor species may have on Hine's emerald dragonfly larvae. Manipulative field experiments with the larvae and potential competitors are important in understanding the outcomes of competitive interactions (Johnson *et al.* 1995); however, these experiments may be difficult. A literature review on competitive interactions among dragonflies would be useful in evaluating possible impacts competitors may have on the larvae.

**2.1.2 Adult ecology.** Conduct studies to determine adult dispersal, habitat requirements, reproductive potential, and interspecific interactions.

Dispersal: Information on adult dispersal of Hine's emerald dragonflies is needed to identify if the patchy distribution of this species represents a metapopulation. An important element of metapopulation dynamics is the ability and tendency of the species to disperse. Research should concentrate on determining the distance Hine's emerald dragonfly adults will fly from a site, corridor use, what habitat types are effective corridors, barriers, and gender differences in dispersal. This information is needed if efforts are made to increase connectivity and dispersal within a population by creating effective corridors. If reintroduction of this species is needed, dispersal distances would be crucial in deciding where the new sites would be located. Mark-recapture studies provide this type of data; however, past mark-recapture studies for this species have identified only a few instances of dispersal. As technology and research advance in this area, new types of studies or methods should be considered as an alternative to the mark-recapture technique. Any type of study will be labor intensive and take multiple years to complete; however, acquiring dispersal data is essential in preserving this species. Genetic markers can also indicate dispersal between subpopulations and populations. Dispersal information would also improve the ability to manage this species and give valuable information on its habitat use.

Habitat requirements: Since it is unclear why Hine's emerald dragonfly does not occur in some areas of suitable habitat, studies should be conducted to better identify the specific habitat requirements of the adults. This information would be useful in management and could inform future habitat restoration and reintroduction attempts.

Reproductive potential: Studies should be conducted to determine the adult reproductive potential of Hine's emerald dragonfly females. Studies should concentrate on estimating the number of eggs laid by one female during one oviposition episode and how many oviposition episodes a female averages in a lifetime. The types of studies that should be conducted include dissections of freshly killed Hine's emerald dragonfly females (e.g., roadkills), when available, and/or females of closely related species to estimate total egg numbers per female. Eggs from induced oviposition by dipping abdomens of freshly killed females in water can also be used in larval ecology studies (task 2.1.1) and for potential reintroduction efforts. Larval studies using these eggs could be used to determine egg and larval development and survivorship, which would aid in evaluating reproductive potential. Determination of differential mortality rates of adult males and females would be important in assessing the recovery criteria. A literature review should be conducted on published studies on other species in the family that pertain to reproductive potential. Estimates of reproductive potential are necessary components of any population dynamics model. Justification of recommended management will be facilitated by the confidence in the population dynamics models. This task is essential to the recovery of this species.

Interspecific interactions: Information on the interspecific interactions of the

adult Hine's emerald dragonfly would be useful in identifying potential competitors and predators that may reduce this species' reproductive potential.

**2.1.3 Model population dynamics.** A metapopulation model should be developed to project population growth of the populations and of each of the subpopulations. Models should use both the present status and the population size from the recovery criteria in order to test for long-term viability (Burgman *et al.* 1993). Using the model, population dynamics would be projected to obtain a better understanding of metapopulation configurations that would promote a 95% probability of species persistence for 100 years, 90% probability of persistence for 100 years, 90% probability of persistence for 500 years, etc. The best available information on population structure and life history would be used for these calculations. Sensitivity analysis would be conducted on values such as dispersal (frequencies and distance), life span, variation in reproductive capability, and variation in mortality to determine which parameters were most influential in long-term persistence of the metapopulation.

Population viability modeling should be used to compare and identify alternative population and metapopulation structures that provide equivalent persistence probabilities. These results may be used to revise recovery criteria or to determine whether an alternative population distribution provides long-term stability equivalent to the recovery criteria.

An attempt should be made to construct a life-table for a typical cohort of Hine's emerald dragonflies (Ubukata 1981, Johnson 1986). Life-tables provide estimates of the proportion of a cohort surviving to each age class. Life-tables often present survivorship, average survivorship, mortality, age-specific mortality rate, and expectation of life throughout the age of a cohort. The survivorship curve, coupled with estimates of age-specific fecundity, provides the data from which estimates of the net reproductive rate and the intrinsic rate of increase may be calculated. These calculations would greatly increase the understanding of the dragonfly's population dynamics. This table would also aid in determining which life stages are most affected by year to year variation in environmental factors and/or are most vulnerable to various threats. Analysis of life-table responses to various threats and management alternatives will allow better decisions and recommendations for the recovery of this species. This task is essential to the recovery of this species.

## **2.2 Monitoring synthesis.**

**2.2.1 Correlate larval and adult population sizes.** Methods should be developed to extrapolate population sizes from larval populations to adult populations. Larval monitoring provides data on population trends over multiple years, which can be applied to management. Larval surveys have advantages over adult surveys, in that larval surveys can be conducted in inclement weather and over a longer period of time. A link between larval and adult populations would allow adult

population estimates to be calculated from larval data; the adult estimates could then be used to determine if the recovery criteria have been met. Understanding the correlation between adults and larvae would be extremely useful in constructing a life-table and toward understanding and evaluating the dragonfly's population dynamics.

**2.2.2 Analyze techniques for estimating population size.** Examine the benefits of various alternative population estimate techniques for adults. Include in this analysis an evaluation of the risk of injury to Hine's emerald dragonfly individuals associated with each method. The alternatives for adults include mark-recapture, removal, transect sampling, exuviae counts, census route, and census stations. Mark-recapture is one of the standard methods of population size estimation. However, information on the dragonfly's population dynamics may need to be determined or calculated in order for the estimation to be accurate. Transect sampling of adults, while less invasive, has the potential to bias counts through double counting. Without handling and marking, however, identifying individuals or even identifying the correct species could be problematic. Platform sampling is a non-invasive, non-destructive method of estimating local adult densities, but it has some of the problems of transect sampling. Comparing the accuracy of each of these techniques would aid in understanding the trade-offs between approaches.

**2.3 Hydrologic studies.** Since it appears that maintaining an appropriate amount of surface and groundwater flow, as rivulets, sheet flow, seeps, and/or springs, is an essential element of breeding habitat, and since the majority of the life cycle of this species is spent as an aquatic life form, the hydrologic regime and water quality become important elements of the habitat. To protect this species, protection from alteration of water quality and quantity is needed. Baseline data should be assembled as to the water flow rates and volumes necessary to provide breeding habitat similar to what exists at the current breeding locations. Basic water chemistry data is needed to assess changes due to watershed development.

Studies should determine the surface and subsurface water regime of sites and recharge areas including quantity and quality. Land use types in the recharge area should be determined, including if the land use is compatible or incompatible with maintaining good water quality. Determine if the surface water or groundwater is contaminated especially with pesticides, herbicides, and fertilizers; if so, locate the source and remedy the situation. If there is a road in the area, determine if there are any hydrologic impacts to the site from the road. An assessment of past and present beaver activity would be beneficial when recommending management techniques to mimic the natural hydrologic cycles of the site. If lake water levels affect the site's hydrology, study the correlation between lake levels and both the site's water regime and larval densities if available.

## **2.3.1 Illinois.**

**2.3.1.1 Lockport Prairie Nature Preserve, Romeoville Prairie Nature Preserve, Middle Parcel, River South Parcel, and Keepataw Forest Preserve.** These sites are all in close proximity to one another on the west side of the Des Plaines River in Will County and share a similar topographic and geologic setting. Other federally and state listed species and rare plant communities that also depend on the groundwater driven moisture regime occur at or near these locations (see Appendix 5). Therefore, the Lower Des Plaines River Groundwater Task Force has been initiated to assemble existing data and explore opportunities to collect additional data aimed at establishing a basic groundwatershed profile. The goal is to provide baseline data that will enable better monitoring of changes over time and more informed review of proposed activities in the groundwatershed. Proactive efforts will include using the results of any studies completed by the task force to enable informed land planning that will be protective of the dragonfly.

**2.3.1.2 Waterfall Glen Forest Preserve.** This preserve surrounds Argonne National Laboratory, which is a Department of Energy (DOE) facility. Argonne National Laboratory is currently engaged in various remediation projects to clean up contamination from earlier disposal programs that predated modern regulations and knowledge. These projects include a pump-and-treat remediation of groundwater contamination. Through section 7 consultation, it was determined that the current program will not affect the seep used by the dragonfly. DOE has agreed to water quality sampling of the seep used by the dragonfly to determine if any contamination is present. Monitoring of the seep and Argonne's activities should continue in consultation with DOE. The lab is also stopping use of their deep well as a potable water source and changing to Lake Michigan water that is piped to the facility. This may increase flows at the seeps, so water levels should be monitored.

**2.3.1.3 Black Partridge Forest Preserve and McMahon Woods.** These sites are both managed by the Cook County Forest Preserve District. No hydrologic studies are planned or occurring for these sites. As part of the environmental documentation for the proposed multi-lane highway adjacent to Black Partridge, a study of the groundwater-fed Black Partridge Creek was completed by the Illinois State Water Survey and Illinois State Geological Survey. This study addressed the amount of groundwater recharge potentially lost to the impervious roadway. Monitoring of the groundwater at these sites would help in their ultimate protection.

**2.3.1.4 Long Run Seep Nature Preserve.** This preserve is the only Hine's emerald dragonfly site located east of the Des Plaines River along its

north-south portion in Will County. Thus, it does not share surface or groundwatershed with the other sites. Development pressure continues within its watershed and monitoring of water quality and quantity should be undertaken to assess impacts.

**2.3.2 Wisconsin.** At this time, hydrology studies are not recommended for Mink River, given the low number of individuals observed at this site, or Piel Creek, because no known larval habitat exists in this area. If Hine's emerald dragonflies are re-discovered at Mink River in significant numbers, hydrology studies should be considered. If larval habitat is located in the Piel Creek area, hydrology studies should be considered.

**2.3.2.1 The Ridges Sanctuary and Mud Lake "North."** Hydrologic studies of The Ridges Sanctuary and Mud Lake "North" area are recommended to better understand the hydrology of this area, identify threats to the water quality, identify recharge areas, and to protect recharge areas, seeps, and springs that are important to Hine's emerald dragonfly habitat. Threats to recharge areas include development and road construction. Studies should include determining the water movement in the larval habitat and the surface and subsurface water regime of the site. This information would aid in the interpretation of the hydrology requirements of larval habitat. This information would also be used to identify the potential sources of water contamination or alterations in hydrology.

The Ridges Sanctuary is located along Lake Michigan's shoreline. Since the hydrology of this site may be affected by rising lake levels, information is needed on the effects Lake Michigan's water level has on the water regime of larval habitat and larval densities. This information would be useful in predicting larval densities and aid in recommending management techniques.

To better understand what hydrologic conditions the Hine's emerald dragonfly larvae have withstood in the Mud Lake "North" site, studies should be conducted to determine historical and present activities that have changed the hydrology of this site, including natural (e.g., beaver impoundments) and human-induced activities (e.g., road development). These studies should include the extent of each activity's alterations to the hydrology and the subsequent changes in habitat. The possible impacts Lime Kiln Road has had as an impoundment on the larval habitat should be evaluated. This information can be used to review potential ways to enhance larval habitat and to help management restore the natural hydrologic properties of this system.

Conduct studies to determine the surface and subsurface water regime of the larval habitat at Mud Lake "North." Evidence indicates the water level at this site varies. Information on water regime would aid in

understanding and maintaining Hine's emerald dragonfly larval habitat and could be used to assess future impacts from hydrologic changes.

**2.3.2.2 Mud Lake "South."** Conduct studies to assess the hydrologic properties of the quarried area. A survey should be conducted to determine if the ponds in the quarried area are increasing the groundwater temperature and lowering the groundwater table.

**2.3.2.3 Arbter Lake.** The surface and subsurface water regime should be assessed at this site to aid in protection and appropriate management actions.

**2.3.2.4 North Bay.** At North Bay, altering the road and/or culvert that presently act to impound water should be explored to increase breeding habitat. This site is located along Lake Michigan's shoreline. Since the hydrology of North Bay is affected by rising lake levels, information is needed on the effects Lake Michigan's water level has on the water regime of the larval habitat and the larval densities. This information would be useful in predicting larval densities and aid in recommending management techniques.

**2.3.2.5 Three Springs Creek.** Hydrologic studies of Three Springs watersheds are recommended to better understand the hydrology of this area and threats to the water quality, and to identify and protect recharge areas and seeps that are important in maintaining Hine's emerald dragonfly habitat. Threats to recharge areas include development and road construction.

**2.3.3 Michigan.** General hydrologic studies should be considered at known sites and new sites. Studies should determine the surface and subsurface water regime of the site and recharge areas including quantity and quality. Land use types in the recharge area should be determined, including if the land use is compatible or incompatible with maintaining good water quality. Determine if the surface water or groundwater is contaminated; if so, locate the source and remedy the situation. The hydrology of the sites has been modified by the construction of roads including a four-lane interstate which divides two known sites. Studies should determine if the hydrologic changes from the roadways have affected Hine's emerald dragonfly habitat and if so, provide potential actions to resolve the impacts. Logging roads and logging road construction may also be a concern to the hydrology of Michigan's sites.

**2.3.4 Missouri.** General hydrologic studies should be considered at known sites and new sites. Studies should determine the surface and subsurface water regime of the site and recharge areas including quantity and quality. Land use types in the recharge area should be determined, including if the land use is compatible or incompatible with maintaining good water quality. Determine if the surface water or groundwater is contaminated; if so, locate the source and remedy the

situation. Where the hydrology of the sites has been modified by the construction of roads, studies should determine if the hydrologic changes from the roadways have affected Hine's emerald dragonfly habitat and if so, provide potential actions to resolve the impacts.

**2.3.5 New sites as they are verified.** General hydrologic studies should be considered at other sites not individually listed here and for new sites that may be discovered in the future. Surface and groundwater regimes should be identified as well as recharge areas. Land use types in the recharge area and impacts on water quality should be determined.

**2.4 Genetics.** Past genetic research on Hine's emerald dragonfly has concentrated on the mitochondrial (mt) DNA, which is passed on by females to their offspring. This information has provided insight on the populations' genetic diversity, health, history, past female dispersal patterns, and phylogeny; however, information from the nuclear genome is needed. Most genetic information is inherited from DNA residing in the nuclei of the cells. Consequently, this DNA should be evaluated for genetic diversity. The nuclear data coupled with information from the mtDNA studies could identify populations with high genetic diversity to be targeted for protection and could guide reintroduction efforts.

## **2.5 Habitat management studies.**

**2.5.1 Evaluate responses to habitat management practices.** Since there has been very little experimental testing of which management strategies are most effective for the Hine's emerald dragonfly, this species' larval and adult responses to habitat management practices need to be studied. This information is needed to develop management plans and strategies for site enhancement and maintenance. These studies should evaluate the short and long-term responses the larvae and adults have to habitat management practices (i.e., prescribed burns, herbicide application, brush removal, and methods for non-native species control). Since prescribed burns are used within Hine's emerald dragonfly habitat, responses from larvae and adults to prescribed burns should be evaluated to determine the positive and negative effects of prescribed burn location and frequency. This may include analyzing data on larval and adult abundances, adult use of burned areas, and fire events. This information would also be useful in predicting the Hine's emerald dragonfly's response to wildfires. A literature review on odonates' and/or other insects' responses to fire and other management techniques would also be useful.

**2.6 Roadkill studies to include strategies for minimizing roadkills.** Studies assessing Hine's emerald dragonfly mortality rate from motor vehicles should continue. Hine's emerald dragonflies have been found dead along roadways in Wisconsin and Michigan (refer to the section under THREATS TO THE EXISTENCE OF THE SPECIES, Significant threats to the existence of Hine's emerald dragonfly, Transportation). In Illinois, no Hine's emerald dragonflies have been collected dead along roads; however,



individuals have been observed flying over roads. The extent to which Hine's emerald dragonfly populations are affected by roadway mortality needs to be determined. The ability to link the mortality of adult individuals to a reduction in population size and/or a loss of genetic diversity is difficult due to the complex population dynamics and life cycle of this species. Ideally, surveys would determine 1) rate of mortality in different traffic conditions, 2) rate of mortality along different roadside habitats, 3) the relative abundance of Hine's emerald dragonfly near roadways, 4) flight behavior along roadways, and 5) how roadways are used by this species. These studies are needed to evaluate the effects from increases in traffic conditions such as speed and volume and to assess impacts from proposed roadway expansions and developments. Because the Hine's emerald dragonfly has been observed flying over railroad tracks used by high speed trains, railway surveys should be also be considered to evaluate the effects high speed trains have on this species.

Strategies and techniques to minimize roadkills should be developed and tested. Techniques may include reducing speed limits, establishing speed bumps, changing roadside vegetation, and placing flight barriers along roadsides to increase flight height across the road.

- 2.7 Water quality monitoring.** It is important to monitor the water quality in Hine's emerald dragonfly larval habitats along roadways, as salt application, siltation, and contaminated surface runoff could negatively affect these habitats. Larval habitat that occurs near roadways or in areas that may be affected by roadways should be evaluated for water quality monitoring. The larval habitat located near the following roadways should be considered for water quality monitoring, as well as other roads that occur within close proximity to Hine's emerald dragonfly habitat.

Illinois: Highway 53, Route 7, Bluff Road, Division Street, New Avenue, and park access roads in Waterfall Glen Forest Preserve

Wisconsin: Lime Kiln Road, State Highways 42 and 57, County Route Q, County Route ZZ, Highland Drive (Door County), and County Route X (Kewaunee County)

Michigan: Interstate 75, Mackinac Trail, and Highway M-123 near Summerby Swamp

It is recommended that water quality should be monitored at least twice a year in August (low flow) and in the spring (high flow). Sampling after a salt application or after a subsequent rain event, would help determine the amount of salt entering the system. If the water has elevated contaminant levels, water quality should be monitored more frequently; the source of contamination would determine the best time for additional samples.

Areas that may not be directly affected by roadways or other potential sources of contamination should also be monitored for water quality. This monitoring would take

place at least twice a year in the fall and in the spring to determine baseline water chemistry and assess shifts in water quality over time.

## **2.8 Effects of environmental contaminants.**

**2.8.1 Contaminants.** Concern about possible harm to the dragonfly from organic contaminants initially arose when the railroad passing through the two largest Illinois population sites was proposed for rehabilitation. This work was originally going to involve replacement of railroad ties with new, creosote-treated ties. Since the evidence available was inconclusive about the mobility and toxicity of the organic components (polycyclic aromatic hydrocarbons) of creosote, steel ties were used instead. The project proponent also agreed to conduct water quality sampling, sediment sampling, and a creosote migration study to assist in determining the mobility of the creosote constituents for future projects. The results of these ongoing studies will be submitted to the USFWS, Chicago Field Office, per a Clean Water Act, Section 404 permit condition that was issued by the Army Corps of Engineers, and will be subsequently made available to the site managers and Recovery Team.

In addition to this forthcoming information on polycyclic aromatic hydrocarbon mobility, more specific data are needed as to the toxicity to the Hine's emerald dragonfly of these and other organic contaminants such as herbicides from lawn care and golf courses. Toxicity testing on closely related odonates would be very useful in assessing impacts from future development in the watershed. This information should be used in conjunction with the hydrologic studies described in task 2.3 to reduce indirect impacts and avoid/minimize harm.

In Wisconsin, contaminants that may be present in the Three Springs Creek watershed include lead and arsenic from an old pesticide mixing station that is upstream of the site near Stagecoach Road and County Highway ZZ, and oil from an old municipal landfill located less than 1 mile upstream on the northeast corner of County Highway ZZ and Sumac Road. Dust and runoff from a parking lot associated with a nearby solid waste transfer facility could also contaminate the watershed. Measures should be explored that could reduce potential contamination of the watershed from the solid waste transfer facility such as paving the parking lot and installing a containment system to hold runoff water. Periodic water quality monitoring should be conducted to determine the presence of pollutants in the watershed, and, if found, measures should be taken to eliminate or contain the contaminant sources. Water quality monitoring for contaminants can be coordinated with the water quality monitoring for roadways and hydrologic studies.

Contaminants present in Wisconsin's Mud Lake "North" watershed could include pesticide residues from the orchard (cherry and apple) industry and from nearby nursery operations. In Illinois, Lockport Prairie Nature Preserve could be affected by pesticides, herbicides, and fertilizers from a nearby golf course.

Other contaminants that could affect Illinois sites include agricultural and residential runoff. Habitat areas should be monitored for contaminants, and, if present, measures should be taken to eliminate or contain the threat.

**2.8.2 Mosquito abatement programs.** Mosquito control treatment methods currently in use include methoprene and the bacterial larvicides *Bacillus thuringiensis israelensis* and *B. thuringiensis sphaericus*. Adult mosquitoes are also controlled through other products such as Permethrin and Resmethrin. Potential threats to the dragonfly from mosquito abatement programs are of two kinds: 1) toxicity impacts from exposure to treatments, through external contact, ingestion, or ingestion of exposed prey items, and 2) potential food chain effects resulting from treatment impacts on both mosquitoes and non-target organisms, including scarcity of prey items and shifts in the species composition of prey, competitors, and predators in the aquatic ecosystem. While many mosquito control products are developed to minimize impacts to non-target organisms, the literature suggests the potential for impacts to Hine's emerald dragonflies from mosquito abatement (Hershey *et al.* 1998). A multi-year study of treated and untreated wetlands in Minnesota observed a response lag in changes in invertebrate communities after larvicide treatments (Hershey *et al.* 1998), indicating adverse impact to this community and the need for additional studies to understand the impact on the Hine's emerald dragonfly. Long-term studies should be conducted to understand impacts on dragonflies and to design abatement programs to avoid/minimize harm.

### **3 CONDUCT SEARCHES FOR ADDITIONAL POPULATIONS.**

Searches for additional Hine's emerald dragonfly populations should be conducted in suitable habitat. Appendix 3 presents descriptions of suitable wetland complexes, descriptions of adult behavior, and other characteristics to consider when searching for Hine's emerald dragonfly. Collaboration with land managers in a potential area may be advantageous in identifying suitable habitat. Locating additional populations would provide information on life history, habitat characterization, and genetic diversity. Because additional populations would play an important role in meeting the recovery criteria, funding will need to be provided to survey for new populations. Dragonfly collections from museums, academia, and other sources should be reviewed to locate misidentified Hine's emerald dragonfly specimens. Locating collected individuals would also provide areas to search for this species. The Illinois State Museum is adding a page to the museum's web site that shows how the Hine's emerald dragonfly may be distinguished from congeners. Electronic listservs will be used to notify entomologists, taxonomists, and museum collection curators of the web page and encourage them to check existing collections for potential Hine's emerald dragonfly specimens.

**3.1 Search for larval habitat within existing sites.** Locating new larval habitat within existing sites would enable appropriate protection and management for these important areas. New larval sites may aid in meeting the recovery criteria and possibly improve the knowledge of larval habitat and life history.

- 3.2 Search for additional populations in Michigan.** Wetland sites in the southern Lower Peninsula, particularly the interlobate region, should be evaluated for suitable habitat. The interlobate region is an area north, west, and southwest of Detroit, which includes St. Joseph, Branch, Kalamazoo, Calhoun, and Jackson Counties and portions of Hillsdale, Washtenaw, and Oakland Counties.
- 3.3 Search for populations in Alabama.** Surveys for Hine's emerald dragonfly should be conducted in potential habitat in northern Alabama.
- 3.4 Search for additional populations in Missouri.** Surveys for Hine's emerald dragonfly should be conducted in Missouri fens. Searches will first center around the site where a specimen was collected in 1999, then expand from there to include fens throughout the State.
- 3.5 Search for additional populations in Wisconsin.** Wetland complexes with surface dolomite deposits along the eastern edge of the southern half of Wisconsin should be evaluated for potential Hine's emerald dragonfly habitat. Potential habitat in Door County should also be surveyed for Hine's emerald dragonflies.
- 3.6 Search for populations in Ohio.** Searches for additional Hine's emerald dragonfly populations should be conducted in Ohio. Efforts to train qualified people to search for additional Hine's emerald dragonfly sites have brought forth suggestions on areas of potential habitat in Ohio.
- 3.7 Search for populations in Indiana.** Searches for additional Hine's emerald dragonfly populations should be conducted in Northeast Indiana.
- 3.8 Search for populations in New York.** Wetlands in New York are thought to be similar enough to the Hine's emerald dragonfly habitat to be surveyed for this species.
- 3.9 Search for populations in Maine.** Wetlands in Maine are thought to be similar enough to the Hine's emerald dragonfly habitat to be surveyed for this species.
- 3.10 Search for populations in Arkansas, Iowa, Illinois, Kentucky, Minnesota, Tennessee, West Virginia, and Canada.** Suitable habitat may exist in these States and in southern Canada. State heritage biologists should be contacted to identify potential habitat. The dolomite bedrock that underlies Hine's emerald dragonfly habitat in the United States extends into Canada in areas with high quality wetlands. Since the Hine's emerald dragonfly's potential range is believed to extend into Canada (see Appendix 3) and a population is located in Michigan near the US/Canadian border, it is highly possible that populations may exist in Canada.
- 3.11 Assess potential for Hine's emerald dragonfly in other states.** Wetland complexes similar to Hine's emerald dragonfly habitat potentially occur in other states not previously mentioned. Possible sites should be identified using knowledge of habitats,

habitat maps, and aerial photographs. Geographic Information System tools such as landcover analyses would also be a useful in locating potential habitat.

#### **4 REINTRODUCTION, INTRODUCTION, AND AUGMENTATION PROGRAM.**

Surveys should be conducted to locate existing populations before reintroduction or introduction of Hine's emerald dragonfly is implemented. Unless an appropriate number of naturally occurring populations are found, establishing self-sustaining populations through reintroduction will be necessary to maintain the long-term viability of the dragonfly.

**4.1 Develop captive rearing protocols.** A captive rearing protocol should be developed in order to propagate Hine's emerald dragonfly larvae. Captive rearing could involve acquiring eggs from wild females and propagating them to a larval stage that will be released at a site. A successful protocol would be the foundation of any introduction, augmentation, or reintroduction efforts. This protocol is an important part of establishing new viable populations, which may be essential in meeting the recovery criteria for this species. This protocol should outline the steps taken to rear the dragonfly eggs through larval development and to transport larvae to release sites. The larval stage with optimal chances of survival to adulthood should also be determined. It may be necessary to use closely related *Somatochlora* spp. to develop a successful protocol before it can be used with Hine's emerald dragonfly. Because large numbers of Hine's emerald dragonfly larvae have not been reared, the protocol may take several years and moderate effort to develop.

**4.2 Implement captive rearing program.** If reintroduction, augmentation, or introduction is needed, a captive rearing program should be implemented after a successful protocol has been developed. Implementation would include rearing eggs from wild females to a larval stage appropriate for release. The implementation program should last as long as Hine's emerald dragonfly individuals are needed for reintroduction, introduction, or augmentation purposes.

**4.3 Assess sites for reintroduction, introduction, or augmentation.** Decisions about reintroduction, introduction, and augmentation sites should be based on the results of the habitat assessment and characterization studies discussed under the larval and adult ecology tasks, and upon genetic considerations. Since seemingly suitable habitats are not presently used by the dragonfly, there may be additional habitat requirements that need to be identified. Reintroduction (moving eggs, larvae, or adults to a separate geographic area within the historic range of the Hine's emerald) within historical range, if appropriate habitat is available, should be a priority. Sites selected for reintroduction should be legally or formally protected, and should have long-term assurances that appropriate management will be carried out for the protection of the new populations.

**4.3.1 Illinois.** Given the importance of the Illinois populations due to the high level of genetic diversity, maintaining and increasing this population seems extremely important for the recovery of the species. This might be a good area to select a

site for experimental reintroduction of Hine's emerald dragonflies, if suitable habitat exists or can be restored. The highly developed urban and industrial nature of the surrounding area, however, severely limit the opportunities for introduction of the dragonflies to new sites. Potential habitat in the lower Des Plaines River valley, such as the Midewin National Tallgrass Prairie, should be investigated for suitability for reintroduction efforts.

**4.3.2 Wisconsin.** Surveys of Door County and the eastern edge of the southern half of Wisconsin should be completed to identify any additional sites supporting Hine's emerald dragonfly populations. Potential reintroduction sites should be identified.

**4.3.3 Michigan.** Previously unknown populations of the Hine's emerald dragonfly have been discovered in 1997 and 1998 from surveys of potential habitat in the Upper Peninsula. Further surveys should be conducted to locate all existing populations before reintroduction is considered in this State.

**4.3.4 Ohio and Indiana.** Identifying suitable reintroduction sites in these two States will be even more difficult, since existing populations are not available for reference assessments and little is known about the reasons that Hine's emerald dragonflies are not currently found at sites with historical records of the species. Since the species is presumably extirpated from both States, future reintroduction efforts should focus on restoring reproducing populations within the historical ranges in each State.

**4.4 Implement reintroduction, introduction, or augmentation.** If the Hine's emerald dragonfly can be successfully propagated and appropriate introduction or reintroduction sites for population establishment have been located, larvae should be released into these sites to establish new populations or subpopulations. The desired goal of this action is to create self-sustaining populations. Due to the 3 year life cycle of Hine's emerald dragonfly larvae, at least 3 years of releases should be conducted. Unless an appropriate number of naturally occurring populations are found, establishing self-sustaining populations through reintroduction or introduction will be necessary to maintain the long-term viability of the dragonfly.

**4.5 Monitor reintroduced, introduced, and/or augmented populations annually.** Population monitoring should be conducted annually to determine the health of the population and the success of the reintroduction. Monitoring may include adult and/or larval surveys. Larval surveys are especially critical since they will detect evidence of reproduction first. This information will provide insight on whether more individuals need to be released at the site and if the population is self-sustaining. This is a long-term task that may take a moderate amount of effort per year.

## **5 CONDUCT AN INFORMATION AND EDUCATION PROGRAM**

- 5.1 Encourage private landowners to conserve the Hine's emerald dragonfly.** Provide education/outreach materials, including management recommendations, to private landowners, organizations, corporations, and other stakeholders to assist in the

development of their own Hine's emerald dragonfly conservation initiatives. Continue or initiate landowner contact to reach people in key habitat areas that are unprotected.

Private landowners with Hine's emerald dragonfly habitat should be contacted and encouraged to protect the dragonfly and its habitat through conservation agreements or deed restricted conservation easements. Landowners should be notified about the presence of the dragonfly and measures they can take to protect the Hine's emerald dragonfly. Coordination with private landowners could be achieved through implementation of a land owner contact program.

- 5.2 Inform local and county governments of Hine's emerald dragonfly recovery goals.** Local units of government should receive information on the Hine's emerald dragonfly and the recovery goals, and the ways they can assist in achieving those goals. The potential for impacts through groundwater contamination and increased groundwater extraction should be prominent topics in this outreach effort. Development of effective partnerships with local governments will help ensure that local land-use decisions benefit the dragonfly's recovery.

- 5.3 Develop outreach material on Hine's emerald dragonfly life history and conservation.** The fact sheet previously developed by the USFWS for the Hine's emerald dragonfly should be updated and revised. This revised fact sheet and other tools should be used in a public education program that includes outreach to schools, local governments, and private citizen organizations. In addition, the public sites in Illinois, Wisconsin, and Michigan can include information about the Hine's emerald dragonfly in their educational programs and in literature distributed routinely to tourists and the general public. People who visit and have an interest in such places as The Ridges Sanctuary, the Will County Forest Preserves, and Hiawatha National Forest should be encouraged to act as an advocacy group and volunteer pool for the protection and recovery of the dragonfly.

## **6 REVIEW AND TRACK RECOVERY PROGRESS**

- 6.1 Maintain a clearinghouse for Hine's emerald dragonfly information.** The USFWS should maintain a clearinghouse for Hine's emerald dragonfly data, progress reports, management plans, habitat conservation plans, guidance documents, and other relevant information.

- 6.2 Conduct Recovery Team meetings at least biannually to evaluate progress.** The USFWS should continue to bring together species experts and land managers represented on the recovery team to evaluate progress toward recovery goals.
- 6.3 Revise plan as appropriate at 5 year intervals.** As research provides more information on the specific requirements and status of this species, the plan should be updated to reflect relevant new information.





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